

## PATENT ABSTRACTS OF JAPAN

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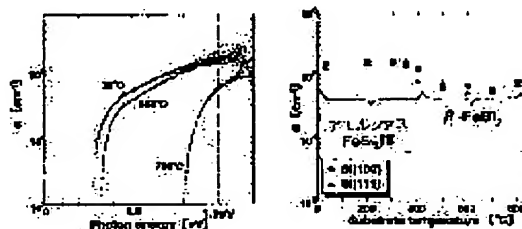
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**(54) AMORPHOUS FERROSILICIDE FILM EXHIBITING SEMICONDUCTOR CHARACTERISTIC AND ITS FORMING METHOD****(57)Abstract:**

**PROBLEM TO BE SOLVED:** To solve the problem that a perfect amorphous ferrosilicide exhibiting semiconductor characteristics similar to those of  $\beta$ -FeSi<sub>2</sub> has not yet attained by cluster ion beam deposition, molecular beam epitaxial growth, ion implantation, or RF magnetron sputtering.

**SOLUTION:** An amorphous FeSi<sub>2</sub> film exhibiting semiconductor characteristics is attained by growing FeSi<sub>2</sub> as a not granular but flat film, i.e., a continuous film, by sputtering on a substrate of lower than 400°C under Ar gas pressure not higher than 5 mTorr using an FeSi<sub>2</sub> alloy target having an atomic ratio of 1:2 of Fe and Si components. Facing target sputtering is especially preferable.

**LEGAL STATUS**

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**CLAIMS**

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[Claim(s)]

[Claim 1] Amorphous iron silicide film in which the semi-conductor property which consists of amorphous FeSi<sub>2</sub> film which has the 0.6-1.0eV band gap obtained by the sputtering method is shown .

[Claim 2] The production approach of the amorphous iron silicide film according to claim 1 characterized by obtaining amorphous FeSi<sub>2</sub> film in which a semi-conductor property is shown by depositing FeSi<sub>2</sub> as continuation film by the sputtering method on a less than 400-degree C substrate under low Ar gas pressure of 5 or less mTorr using the FeSi<sub>2</sub> alloy target of the component atomic ratio 1:2 of Fe and Si.

[Claim 3] The production approach of the amorphous iron silicide film according to claim 2 that the sputtering method is characterized by being the opposite target type sputtering method.

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**DETAILED DESCRIPTION**

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[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the amorphous iron silicide film in which a semi-conductor property is shown, and its production approach.

[0002]

[Description of the Prior Art] The application to a solar battery element or the light emitting and receiving element for a communication link is expected with the semi-conductor of the direct transition mold in which beta-FeSi<sub>2</sub> has a 0.85eV band gap. This invention person developed the approach of depositing FeSi<sub>2</sub> thin film of a parent phase, previously deposited on a substrate by the laser ablation method (JP,2000-178713,A).

[Problem(s) to be Solved by the Invention] Although it is indicated by JP,1-31453,B that the amorphous film of zeta-FeSi<sub>2</sub> phase with which Si makes the stable solid solution in 69 - 72.5at% shows a semi-conductor property. This amorphous film is manufactured with the ionized cluster beam vacuum deposition which is made to inject Fe and Si from separate closed mold crucible, and vapor-deposits them. Si is a 68at(s)% thing, the value of electrical conductivity sigma is 1ohm-1cm-1 at 590 degrees K, and a band gap is 1.258eV and does not show the property near beta-FeSi<sub>2</sub>.

[0003] Although it is necessary to make it quench with the substrate of the low temperature which was in the high energy possible condition, and an atom-like particle is made to reach a substrate, and is not heated, or was cooled in order to obtain the good amorphous structure film. Also in the RF magnetron sputtering method considered to be most suitable for obtaining the amorphous structure film compared with other existing approaches, such as ionized cluster beam vacuum deposition, molecular beam epitaxy, and ion-implantation. By the usual approach, in order to touch the film which the plasma is depositing, while the film receives damage, a microcrystal generates in response to annealing-effectiveness. The amorphous iron silicide which has the semi-conductor property of the property near beta-FeSi<sub>2</sub> that it is hard to obtain the perfect amorphous film is not obtained until now.

[0004]

[Means for Solving the Problem] When this invention person used the sputtering method in which high energy particle deposition is possible, by depositing the flat film which is not granular, i.e., the continuation film, FeSi<sub>2</sub> of a very good amorphous condition was obtained, and FeSi<sub>2</sub> of this amorphous condition found out that the semi-conductor property of the property near beta-FeSi<sub>2</sub> was shown.

[0005] That is, this invention is amorphous iron silicide film in which the semi-conductor property which consists of amorphous FeSi<sub>2</sub> film which has the 0.6-1.0eV band gap obtained by the sputtering method is shown. Furthermore, this invention is the approach of producing amorphous FeSi<sub>2</sub> film in which the semi-conductor property of the property near beta-FeSi<sub>2</sub> which has a 0.6-1.0eV band gap using the FeSi<sub>2</sub> alloy target of the component atomic ratio 1:2 of Fe and Si by depositing FeSi<sub>2</sub> as continuation film by the sputtering method on a less than 400-degree C substrate under low Ar gas pressure of 5 or less mTorr is shown.

[0006] Amorphous FeSi<sub>2</sub> is obtained by the low voltage sputtering method under low Ar gas pressure of 5 or less mTorr. Especially, amorphous FeSi<sub>2</sub> better film can be grown up by the opposite target type sputtering method.

[0007] Drawing 1 is the conceptual diagram showing the principle of the opposite target type DC sputtering method. By this approach, the plasma is completely shut up between a target 2 and a target 3 by electric field E and the magnetic field B impressed in parallel, in order that the plasma may not touch targets 2 and 3 and the

substrate 1 arranged perpendicularly, only a neutral particle accumulates on a substrate 1, in order that the growth film may not receive damage by the plasma and may not receive annealing-effectiveness, a microcrystal does not generate, but the better amorphous film is obtained. Moreover, since there are few skin temperature rises of the deposition film, the continuation film (as-growth) can be grown up.

[0008] Moreover, the film obtained since the re-sputter by plasma contact did not happen has the very small presentation gap from a target, and a FeSi<sub>2</sub> alloy target can be used like the laser ablation method. Furthermore, 5 or less mtorrs and since [ desirable ] low voltage sputtering of 1 or less mtorr is possible, the emitted particle (atom) from a target reaches a substrate, maintaining high energy without almost colliding with Ar gas for spatters. Also by the same sputtering method, growth of the better amorphous iron silicide film is attained with the above two improving points compared with the RF magnetron sputtering method.

[0009] The property improvement by addition of other elements effective in the amorphous film can realize the opposite target type sputtering method easily like the laser ablation method. By the usual sputtering method, as the film which the plasma is forming is not touched, when making it annealing-effectiveness not act, the good amorphous film can be obtained, but by the opposite target type sputtering method, since it is a plasma free-lancer, the amorphous film is obtained easily. Therefore, lamination is also easy. It is suitable also for large area-ization and industrial application is easy.

[0010] Moreover, magnetic-semiconductor-izing by adding a magnetic element and adjustment of the carrier concentration by hydrogenation are possible for amorphous iron silicide. Furthermore, amorphous iron silicide has an unnecessary substrate heating device, in order to grow up at a room temperature.

[0011]

[Example] The iron silicide thin film of about 240nm of thickness was produced from the room temperature on Si (100) and a substrate (111) by the PATTA Ling's method in the 400-degree C temperature requirement using the example 1 opposite target type DC sputtering system (Thin film Software company make, mirror TRON sputtering system MTS-L2000-2T). The iron silicide thin film was similarly produced in the temperature requirement 400 degrees C or more for the comparison. FeSi<sub>2</sub> alloy (99.99%) of the presentation ratio 1:2 was used for the target. The inside of a sputtering chamber was exhausted to 10<sup>-4</sup> or less Pa using the turbo molecular pump, and Ar gas of 15.0sccm(s) was flowed at the time of membrane formation, it set gas pressure to 1.0mTorr(s), and set applied voltage and a current to 950mV and 6.0mA, respectively. The rate of sedimentation was 1.0 nm/min.

[0012] SEM observation, an X diffraction, light absorption spectrum measurement, and electric resistance measurement performed evaluation of the creation film. It turned out that substrate temperature is the amorphous film at less than 400 degrees C by X diffraction measurement. By absorption spectrum measurement, amorphous FeSi<sub>2</sub> showed the 0.6-0.7eV band gap.

[0013] Drawing 2 shows the SEM image in which the change to the substrate temperature of the shape of film surface type of iron silicide is shown. Irrespective of substrate temperature, the sample front face is very smooth. Irregularity slightly like a wave was observed at 800 degrees C. Drawing 3 shows the substrate temperature dependence of an X-ray diffraction pattern. It turns out that substrate temperature is acquired for amorphous FeSi<sub>2</sub> at less than 400 degrees C, and beta-FeSi<sub>2</sub> is obtained above 400 degrees C.

[0014] Drawing 4 shows the substrate temperature dependence of a light absorption spectrum and an absorption coefficient  $\alpha$ .  $\alpha=1.3-1.6 \times 10^5 \text{cm}^{-1}$  and polycrystal beta-FeSi<sub>2</sub> film of amorphous FeSi<sub>2</sub> film are  $\alpha=5.0-7.8 \times 10^4 \text{cm}^{-1}$ . Drawing 5 shows the substrate temperature dependence of a light absorption spectrum and the optical band gap Eg. 0, 64-0.82eV, and polycrystal beta-FeSi<sub>2</sub> film of amorphous FeSi<sub>2</sub> film are 0, 84-0, and 94eV. Drawing 6 shows the substrate temperature dependence of sheet resistance and specific resistance  $\rho$ . The resistivity  $\rho$  of amorphous FeSi<sub>2</sub> film is  $3.2 - 7.3 \times 10^{-3} \text{ohmcm}$ , and the resistivity  $\rho$  of polycrystal beta-FeSi<sub>2</sub> film is  $1.0 - 3.2 \times 10^{-1} \text{ohmcm}$ .

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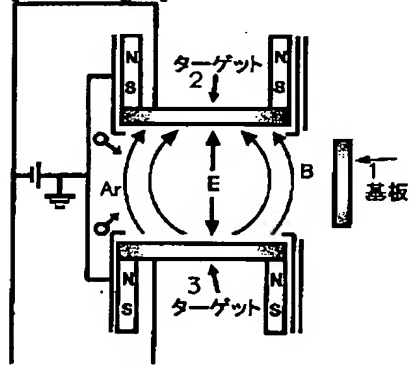
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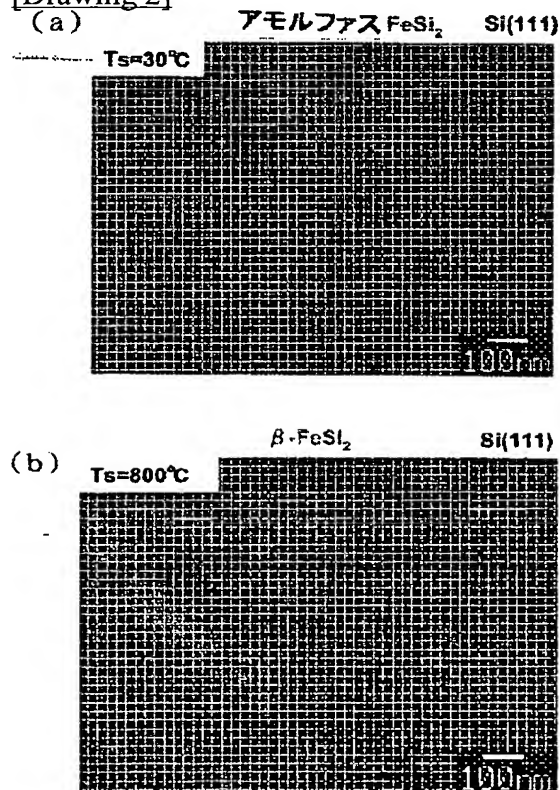
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## DRAWINGS

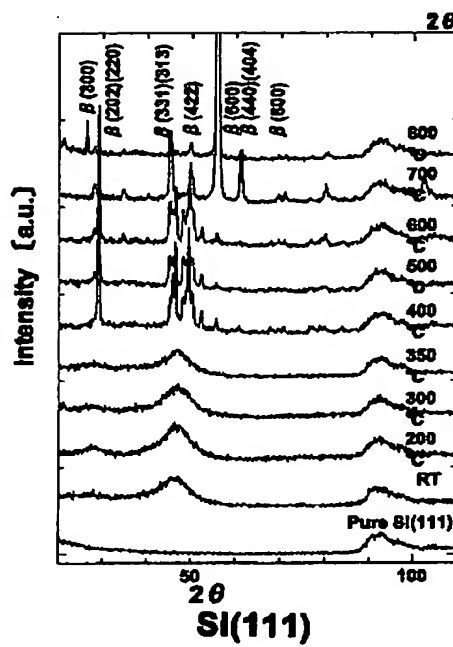
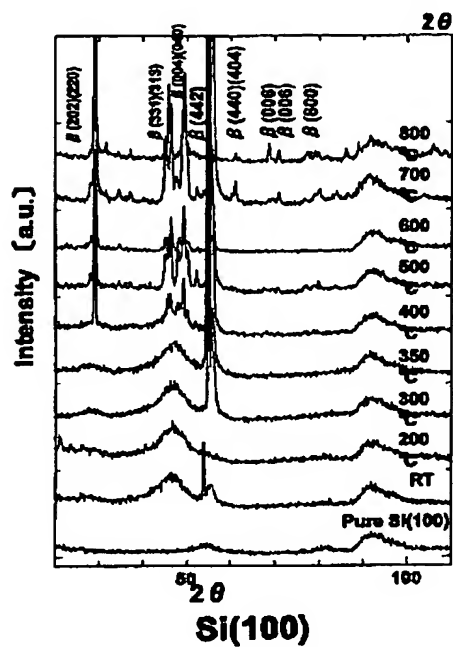
[Drawing 1]



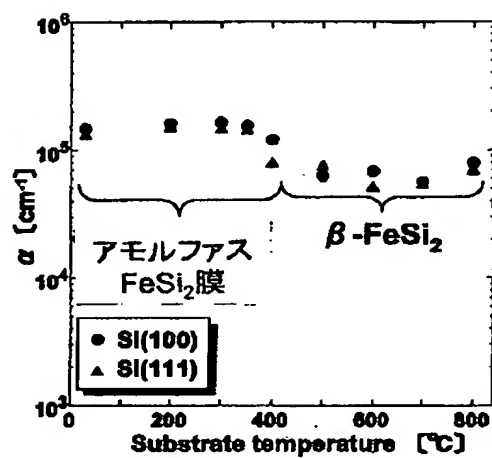
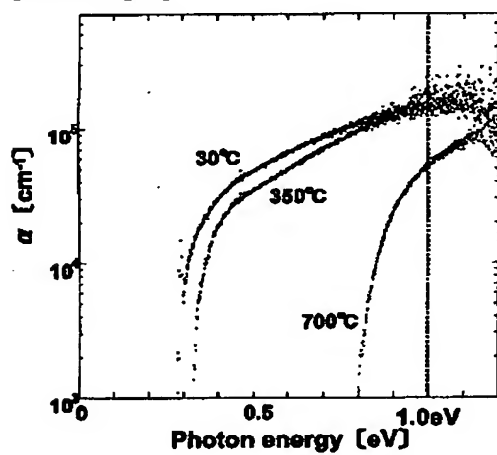
[Drawing 2]



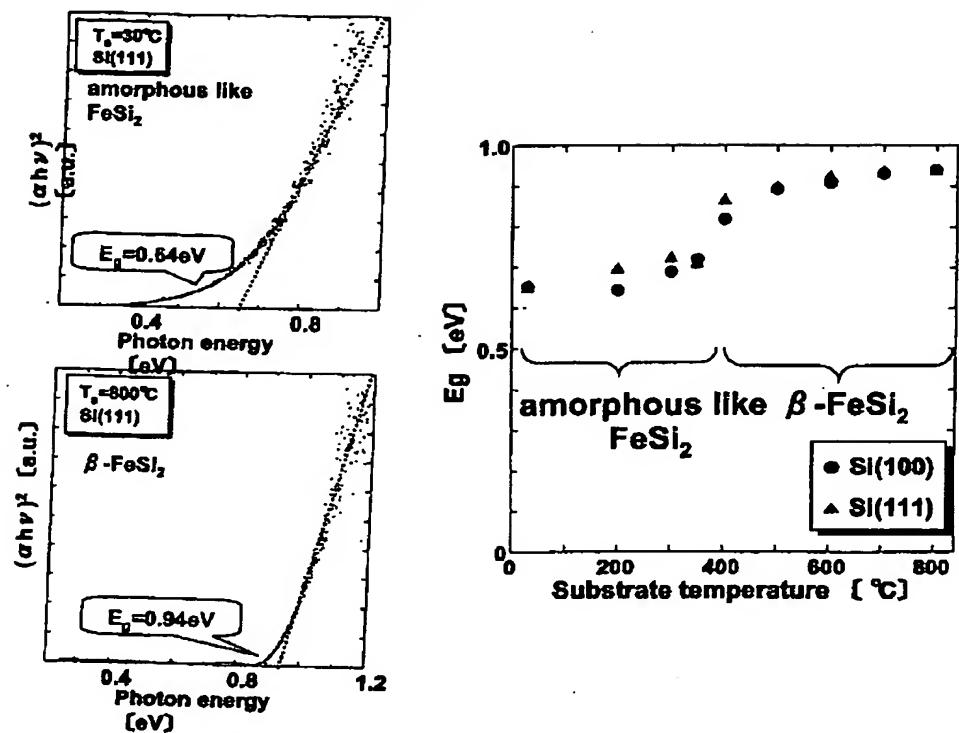
[Drawing 3]



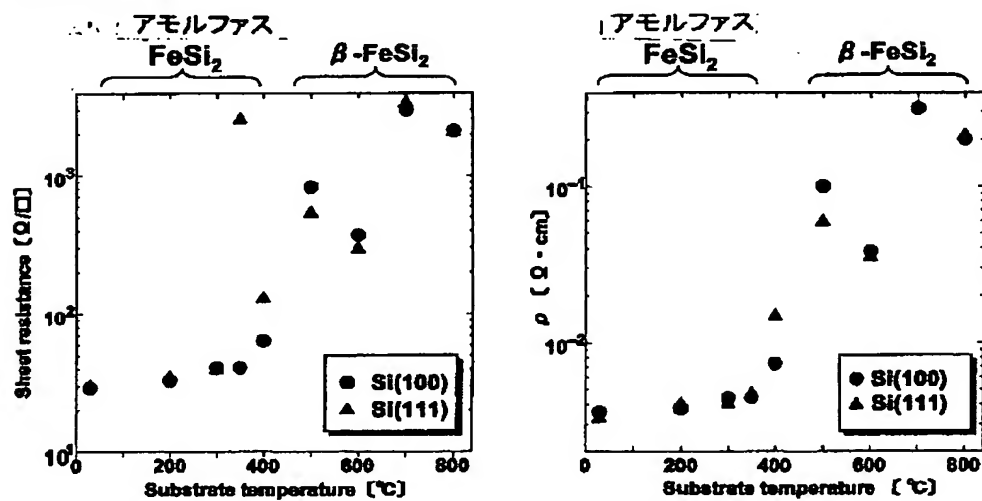
[Drawing 4]



[Drawing 5]



[Drawing 6]



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CORRECTION OR AMENDMENT

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[Kind of official gazette] Printing of amendment by the convention of 2 of Article 17 of Patent Law  
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 [Publication date] April 7, Heisei 17 (2005. 4.7)

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[Procedure revision]  
 [Filing Date] May 13, Heisei 16 (2004. 5.13)  
 [Procedure amendment 1]  
 [Document to be Amended] Specification  
 [Item(s) to be Amended] 0011  
 [Method of Amendment] Modification  
 [The contents of amendment]  
 [0011]  
 [Example]

The iron silicide thin film of about 240nm of thickness was produced from the room temperature on Si (100) and a substrate (111) by the PATTA Ling's method in the 400-degree C temperature requirement using the example 1 opposite target type DC sputtering system (Thin film Software company make, mirror TRON sputtering system MTS-L2000-2T). The iron silicide thin film was similarly produced in the temperature requirement 400 degrees C or more for the comparison. FeSi<sub>2</sub> alloy (99.99%) of the presentation ratio 1:2 was used for the target. The inside of a sputtering chamber was exhausted to 10<sup>-4</sup> or less Pa using the turbo molecular pump, and Ar gas of 15.0sccm(s) was flowed at the time of membrane formation, it set gas pressure to 1.0mTorr(s), and set applied voltage and a current to 950V and 6.0mA, respectively. The rate of sedimentation was 1.0 nm/min.

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